U. S. DEPARTMENT OF AGRICULTURE
FARMERS' BULLETIN No. 1676

LUBRICATING-OIL SPRAYS FOR USE ON DORMANT FRUIT TREES

Rev.ed. follows

LUBRICATING-OIL EMULSIONS have in recent years come into very general use in the dormant and delayed-dormant spraying of deciduous-fruit orchards and yard trees in most parts of the country and to a lesser extent for trees in foliage. This bulletin gives directions for the preparation, storage, and use of lubricating-oil emulsions, describes the different emulsifiers which have been found suitable for the preparation of these sprays, and gives specifications to guide the grower in selecting the proper kind of oil for use in orchard spraying. The orchard insects which may be readily controlled by the use of oil are briefly discussed, and the proper strength of lubricating-oil emulsion for the control of each species is indicated.

Washington, D. C. Issued September, 1931

LUBRICATING-OIL SPRAYS FOR USE ON DORMANT FRUIT TREES

By A. L. QUAINTANCE, formerly *Associate Chief of Bureau, in Charge*, E. J. NEWCOMER, *Senior Entomologist*, and B. A. PORTER, *Entomologist, Division of Deciduous Fruit Insects, Bureau of Entomology*[1]

CONTENTS

INTRODUCTION

WHEN USED IN ORCHARD SPRAYING, oils should be mixed with water, in order that they may be applied economically and with safety to the trees. While not soluble in water, oil may be more or less evenly distributed in water by a process known as emulsification, in which the oil is broken up into extremely fine droplets (fig. 1), similar to the globules of butterfat in milk. The emulsifier holds the oil globules apart and prevents the separation of the oil from the water.

Two general classes of petroleum oil sprays are usually recognized, miscible oils and oil emulsions, the distinction being based on the character of the stock, or concentrated material. In the preparation of stock emulsions the oil is broken up into fine globules, and water is included in the mixture in proportions ranging up to 50 per cent. These stock emulsions vary in consistency from that of thin cream to that of a thick, jellylike paste. In the case of a miscible oil, the emulsifier is dissolved in the oil, and the concentrated material is prepared with very small quantities of water, which results in a clear stock, similar in general appearance to ordinary lubricating oil. When diluted, however, emulsions and miscible oils are very similar, the chief difference being that the

[1] The experimental information on which this bulletin is based has been obtained by a number of workers in the Bureau of Entomology and elsewhere. Apparently the first experiments with lubricating-oil emulsions for the control of insects attacking deciduous fruits were conducted at Bentonville, Ark., by A. J. Ackerman, in 1921–22. Since that time work with lubricating-oil sprays has also been conducted by the Bureau of Entomology at Yakima, Wash., by E. J. Newcomer and M. A. Yothers; at Fort Valley, Ga., by O. I. Snapp, C. H. Alden (resigned), and H. S. Swingle (resigned); at Vincennes, Ind., by B. A. Porter and R. F. Sazama; at Sligo, Md., by E. H. Siegler and Luther Brown; and at Washington, D. C., by C. H. Richardson (resigned) and R. C. Burdette (resigned). R. C. Roark, of the Bureau of Chemistry and Soils, and E. L. Griffin, of the Food and Drug Administration, have cooperated in the chemical and certain other technical phases of the oil investigations.

oil droplets in a miscible oil are as a rule considerably smaller than those found in a diluted emulsion.

In dealing with oil sprays, the grower should keep in mind the fact that the dispersal of oil in water is in many cases a very temporary condition and that at the first opportunity the oil and the water may follow their normal tendency and separate into distinct layers, which do not readily mix again. This separation of oil, or "breaking" of the emulsion, renders the spray unsuitable for use, since the greater part of the liquid in the tank then contains insufficient oil for proper effectiveness, while the remainder of the tank load contains such a high proportion of oil that injury to the treated plants may result.

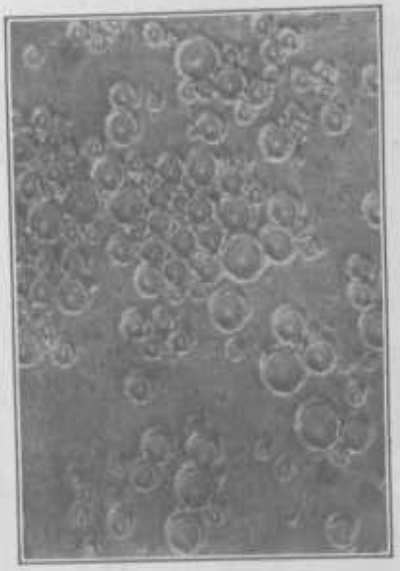

FIGURE 1.—Diluted oil emulsion, magnified 400 times to show the tiny globules of oil floating in the water

A complete separation of the oil as just described should not be confused with "layering," or "creaming," which occurs with many oil sprays, usually after they are diluted. Layering is analogous to the rising of cream on milk, the cream in this case consisting of the globules of oil, accompanied by the emulsifier and any other solid or semisolid materials which may be present. While creaming often results in apparently distinct layers of materials, a moderate amount of stirring or agitation restores the entire mixture to its original uniform condition.

When diluted in the spray tank, the different oil sprays vary greatly in their tendency to separate, or break down. In general, the miscible oils are more stable than the emulsions.

LUBRICATING-OIL EMULSIONS

In recent years it has been found that emulsions prepared from certain cheap lubricating oils are remarkably effective at low concentrations, and these efficient and economical oil sprays have come into very general use in the control of the San Jose scale and of certain other insects in the deciduous-fruit orchards in many parts of the country. For a few years after lubricating-oil emulsions were first introduced, many orchardists prepared their own stock material, but at present most of it is made by insecticide manufacturers, or by small local plants supplying near-by growers. A number of orchard men, however, are still making their own stock emulsion, utilizing farm labor which would otherwise be less profitably employed during slack periods through the winter months. For the benefit of such growers and others, detailed directions are here given for the preparation of a number of different kinds of oil emulsion.

The making of lubricating-oil emulsions, as well as their use in the orchard, should be carefully supervised, in order that the oil may be properly emulsified and properly diluted. If a scum of free oil is found in the spray tank, the cause should be determined, and the condition corrected before any further spraying is done. A broken emulsion, in which the oil has risen to the top in a separate layer, is unfit for spraying purposes.

OIL SPECIFICATIONS

The oils which have been found suitable for the dormant spraying of deciduous-fruit trees are the lighter lubricating oils, such as are used in slow-moving bearings, and some of the oils ordinarily used for floor dressings. Such oils have sometimes been referred to as "red engine" oils, but this term is too indefinite for use when buying oil for the control of insect pests. Certain technical specifications will describe more definitely the type of oil which has been found most satisfactory. The important properties appear to be viscosity [2] and volatility.[3]

The viscosity which an oil should possess, to be suitable for dormant spraying, seems to vary somewhat in different parts of the country, apparently because of climatic conditions. In northwestern Arkansas oils having a viscosity of about 200 seconds Saybolt have been found to have the maximum effectiveness, and oils of this viscosity are used by most of the growers in the Ozark fruit districts. Workers in the southeastern part of the United States recommend oils having a viscosity of 125 seconds Saybolt or more. In the more northern fruit sections oils having a viscosity of 90 to 100 seconds Saybolt seem to give as good results as the more viscous ones, possibly because the lower temperatures which normally prevail during the dormant season permit the oil to remain longer on the trees. For summer spraying, oils having a viscosity of a little less than 90 seconds Saybolt are often used.

The volatility should be low; in other words, the oils should be of such quality that they will not evaporate too quickly.

A third specification, known as the unsulphonated residue, indicates the degree of refinement of the oil. This is expressed as a percentage, a high value indicating a high degree of refinement. While this property is of significance chiefly in connection with oils for summer spraying, the recommendations in the Northwest [4] call for oils showing an unsulphonated residue of not less than 50 per cent. This is broad enough to include the majority of the lubricating oils in common use for spraying purposes.

The base from which the oil is derived, either asphalt or paraffin, appears to be of no special importance.

---

[2] Viscosity is specified technically in seconds—the length of time it takes a given quantity of oil to pass through a given opening under standard conditions. (Most frequently determined in the Saybolt universal viscosimeter at 100° F.)

[3] Volatility is measured by the percentage of the oil which evaporates under certain standard conditions.

[4] Recommendations made by the western cooperative oil-spray project (a group of investigators in the Northwest) for 1931.

FORMULAS AND DIRECTIONS FOR PREPARATION AND USE

SOAP-OIL EMULSIONS

Probably the most widely known lubricating-oil emulsion is that prepared according to a formula developed by W. W. Yothers, of the Bureau of Entomology, for use in the control of citrus pests, and first found effective in the control of the San Jose scale by A. J. Ackerman, also of the Bureau of Entomology. This formula utilizes soap as the emulsifier, and heat is necessary for its preparation.

BOILED SOAP-OIL EMULSION

Lubricating oil	1 gallon.
Potash (potassium) fish-oil soap	1 pound.
Water	½ gallon.

The soap ordinarily used is a liquid potash fish-oil soap containing 30 per cent or more of soap by weight. Potash soap is more

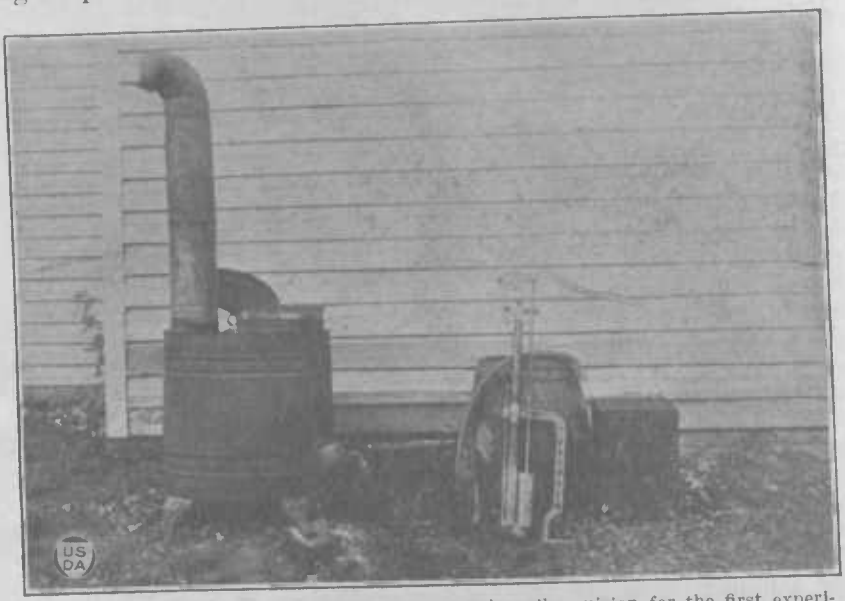

FIGURE 2.—Equipment which was used in preparing oil emulsion for the first experiments with lubricating-oil emulsion on deciduous orchard trees, and suitable for making small quantities of material

satisfactory than soda soap, because it does not become hard on cooling. The water used should be soft if possible, like rain water.

The ingredients are mixed together, the whole brought to a boil, and then, while still hot, pumped at least twice through a small opening, such as that in a spray gun or a very coarse disk nozzle. The emulsion should be pumped from one container into another, rather than back into itself, so that all of the material will pass through the pump. A bucket pump (fig. 2), vigorously used, will give a good emulsion, although for making large quantities a power-driven pump is of course desirable. The emulsions made with the larger pumps are usually more stable than those made with a bucket pump,

and will keep for longer periods of time, since the greater pressure breaks the oil up into finer droplets. Hot oil is very destructive to fiber or rubber pump packing, and if large quantities of emulsion are to be prepared, metal packing will be necessary. Various sources of heat have been successfully employed. Some manufacturers use a steam-jacketed copper kettle, while others use live steam, introduced into the mixture through a coil in the bottom of the cooking vat. (Fig. 3.)

Certain modifications of the foregoing formula have been suggested from time to time. In some cases the quantity of soap has been increased to insure stability when slightly hard water must be used for diluting the emulsion. If very hard water must be used for spraying, however, some other means of preventing the breaking of

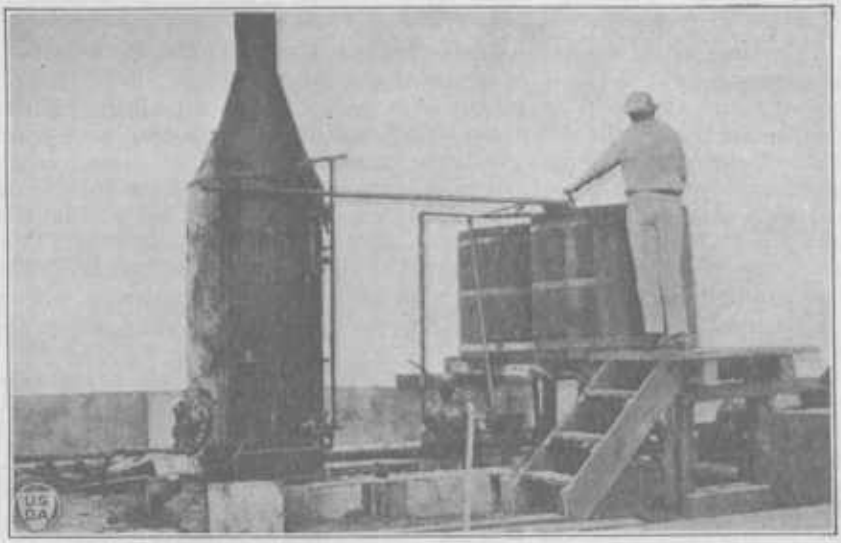

FIGURE 3.—Equipment suitable for the preparation of oil emulsion on a commercial scale. The cooking is done by live steam from the boiler

the emulsion must be employed. Another modification has been a reduction in the quantity of water used, the chief advantages being a saving in storage space and a lessening of the danger of freezing. The water content of a stock emulsion made according to this formula may be reduced to 25 per cent (one-fourth of a gallon of water for each gallon of oil); beyond this point certain difficulties may develop.

The standard formula ordinarily results in a stock containing approximately 66 per cent of actual oil by volume,[5] although some allowance has to be made for the manner of manufacture. If the stock is cooked in a shallow container over an open fire, excessive evaporation may unduly reduce the volume of water, and thus increase the proportion of oil. The use of live steam causes a slight increase in the quantity of water present. The pumping sometimes

[5] Throughout this bulletin the oil content both of stock emulsions and of diluted oil sprays is expressed as the percentage of oil by volume.

incorporates more or less air into the mixture, but the emulsion usually shrinks to normal volume on standing and cooling.

COLD-STIRRED SOAP-OIL EMULSIONS

Several formulas have been developed for the preparation of soap-oil emulsions without the use of heat, the ingredients being merely stirred together. No water, except that present in the fish-oil soap, is used in these formulas. This type of emulsion has been used by a number of growers, who have found it quite satisfactory. Two formulas will be given.

Resin fish-oil soap emulsion[6]

Lubricating oil	9 gallons (about 65 pounds).
Resin fish-oil soap[7]	1 gallon (about 8 pounds).

Pour the soap into a suitable container, then add a quantity of oil not to exceed one-third of the volume of the soap. Stir the oil rapidly into the soap by means of a paddle until all of the oil has disappeared into the soap, and the mixture has become somewhat stiff. Continue to add successively larger quantities of the oil (each additional quantity of oil never to exceed one-third of the total bulk of the mixture). Stir in thoroughly each addition of oil and do not add more until the emulsion has a stiff jellylike consistency. This procedure should be continued until the required quantity of oil has been emulsified. This emulsion may be made in a small way with a bucket and paddle; for quantity production a power mixer is desirable. (Fig. 4.)

The stock emulsion made according to this formula contains approximately 90 per cent of oil by volume. It should be stored in air-tight containers. Any free oil found on the surface can be stirred into the mixture without difficulty. In diluting this jellylike stock, work small quantities of water into it at the start, instead of putting the stock material directly into large quantities of water.

Cold-stirred soap-oil emulsion

Lubricating oil	1 gallon.
Soap (potash fish-oil soap, 30 per cent actual soap)	1 pound.

Stir the soap and oil together as directed above.

USE OF SOAP-OIL EMULSIONS WITH HARD WATERS

When a soap-oil emulsion is diluted with hard water, which is the only water available in many orchards, the soap is immediately attacked by the calcium or other mineral salts present, forming insoluble soaps which are then useless as emulsifiers. This liberates the oil, which rises to the surface in the spray tank. If the water is only slightly hard, the use of a little additional soap in the preparation of the emulsion will often overcome the difficulty. The emul-

[6] A more complete discussion of this emulsion will be found in a mimeographed circular, E-277, by E. H. Siegler and Luther Brown, issued by the Bureau of Entomology in March, 1930.

[7] A resin fish-oil soap much used in preparing these emulsions has approximately the following composition: Fish-oil soap, 16 per cent; resin soap, 47 per cent; water, 37 per cent.

sions prepared with resin fish-oil soap are more resistant to the action of hard water than those made according to the standard formula, but even these break down in some hard waters.

The difficulty with hard water has been successfully overcome in many eastern and middle-western fruit districts by making a weak Bordeaux mixture (½–½–50) with the water used in diluting the emulsion, before the oil-emulsion stock is added. When the soap is eliminated by the action of the hard water, the Bordeaux acts as a substitute emulsifier, and maintains the emulsion. The resulting mixture layers rather rapidly, however, and a moderate amount of agitation is needed to insure a uniform emulsion. The agitation

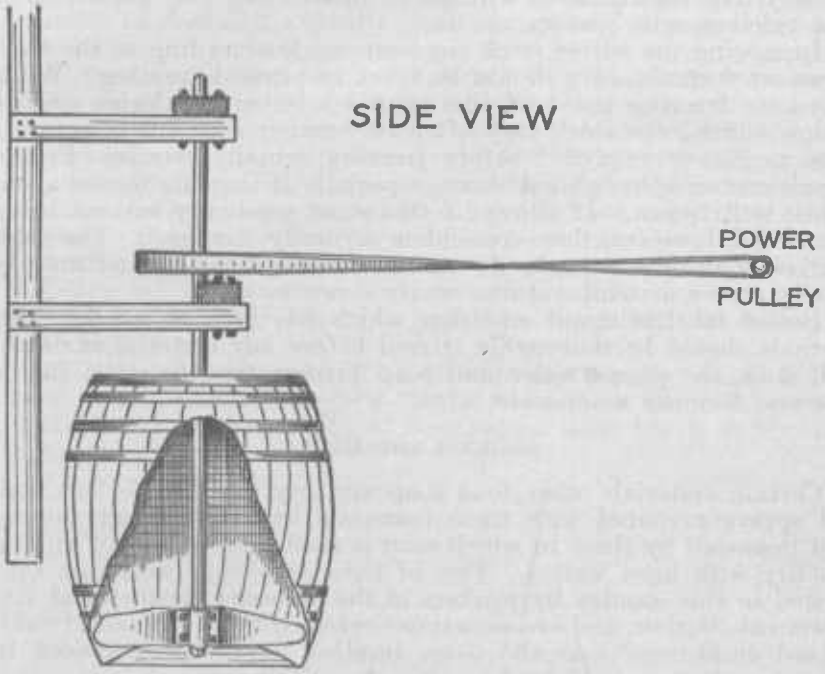

FIGURE 4.—Equipment used for the preparation of resin fish-oil soap-oil emulsion on a small commercial scale. This sort of equipment is also suitable for making other cold-stirred soap-oil emulsions. (After Siegler and Brown. See footnote 6)

provided by present-day sprayers is more than adequate for this purpose. The use of Bordeaux mixture to overcome the action of hard water on soap emulsions involves bothering with additional ingredients, but the growers in some eastern and middle-western districts have adopted this practice. In other districts, especially in the Northwest, the tendency has been toward the use of the soapless emulsions.

Sometimes the presence of residues of lime-sulphur or Bordeaux mixture in the spray tank causes oil emulsion to break down in a similar manner as occurs with hard water. All such foreign matter should be washed out of the spray tank before the use of a soap-oil emulsion is attempted.

STORAGE OF SOAP-OIL EMULSION

A well-made soap-oil stock emulsion is stable for a fairly long period, and no difficulty is likely to be experienced if the quantity required for an entire dormant season is stored from fall until spring. A gradual separation takes place, however, and stock emulsions carried over from one year to the next are often in poor condition the second season.

Stock emulsions should be stored in clean containers. Old lime-sulphur barrels should not be used for storing soap-oil emulsions, since it is almost impossible to remove the lime-sulphur so completely that the emulsion will not be broken down by the action of the calcium salts present.

In storing the boiled stock emulsion made according to the Government formula, care should be taken to prevent freezing. While the true freezing point of this emulsion is only a degree or two below 32° F., the stock may often be "undercooled" to a point as low as 25° or even 20° before freezing actually sets in. Frozen emulsions sometimes break down, especially if they are moved about while still frozen. If allowed to thaw out gradually without being disturbed, however, they are seldom seriously damaged. The cold-stirred soap-oil emulsions do not freeze very readily, and may be safely stored at temperatures nearly down to zero.

Boiled lubricating-oil emulsion which has been stored for long periods should be thoroughly stirred before any material is drawn off, since the excess water and soap present tend to settle to the bottom, forming a separate layer.

SOAPLESS EMULSIONS

Certain materials other than soap are very good emulsifiers, and oil sprays prepared with these materials have certain advantages not possessed by those in which soap is used, chiefly that of mixing readily with hard waters. Two of these emulsions were first suggested in this country by workers at the Missouri Agricultural Experiment Station, and are sometimes referred to as "Missouri cold-mixed emulsions." As the name implies, no heat is required in their preparation. These formulas are as follows:

CALCIUM CASEINATE-OIL EMULSION

Lubricating oil	1 gallon.
Calcium caseinate	2 ounces.
Water	½ gallon.

With a small quantity of water, work the calcium caseinate into a thin paste free from lumps; add the remainder of the water and then the oil; pump several times from one container into another through a small opening, such as that in an ordinary spray gun. The preparation of satisfactory cold-mixed emulsions requires greater pressures than are needed in making the boiled soap-oil emulsion, and an ordinary bucket pump is often inadequate for this purpose. Much better emulsions may be made with a power-driven pump. The calcium caseinate should be fresh, since material which

has been on hand for long periods is often unsuitable for use as an emulsifier. The stock emulsion prepared according to this formula should be used within a day or two of the time it is prepared; if stored for longer periods, the oil often separates, making it impossible to obtain a uniform emulsion when it is diluted. Some growers use a power sprayer for preparing these emulsions, making up either a day's requirements when starting operations in the morning or enough for each tank load as needed. In preparing large quantities, the material is mixed in the spray tank, pumped into barrels or other containers, and then pumped back and forth until emulsification is complete. For this purpose an overhead suction hose is convenient. In making only enough for a tank load at a time, the quantity of material is usually small enough so that a good emulsion may be made by merely pumping it through the spray nozzle back into itself for a few minutes before filling the tank with water. When small quantities of oil are mixed in this way, a little of the stock mixture may be forced into the air-pressure chamber, and is retained there until the pressure runs down when the tank is about empty. At this point, this concentrated oil flows from the pressure chamber back into the tank and is sprayed out with the last few gallons. This means that for the most of the tank load the oil content of the spray is slightly below the required dilution, while at the very end it is stronger than necessary. Releasing the pressure for a moment after the tank has been filled will overcome this difficulty.

The calcium caseinate-oil emulsions are usually unaffected by hard waters, although in New Mexico it has been found that waters containing large quantities of magnesium salts break down emulsions of this type.

BORDEAUX-OIL EMULSIONS

Lubricating oil	1 gallon.
Copper sulphate	2 ounces.
Hydrated lime	3 ounces.
(or unslaked lime	2 ounces).
Water	½ gallon.

Dissolve the copper sulphate in the greater part of the water. (The copper sulphate should be dissolved in a nonmetal container.) Stir the lime into the remainder of the water, then add it to the copper sulphate solution, stirring vigorously. In other words, prepare a Bordeaux mixture. Add the oil, and pump as outlined for the preparation of the calcium caseinate-oil emulsion. As with the calcium caseinate-oil emulsion, the stock should be used within a few days of the time it is made. Both of these soapless emulsions layer rather rapidly when diluted, and vigorous agitation should be maintained in the spray tank at all times.

Bordeaux-oil emulsion may also be prepared in the spray tank as needed, a tank load at a time. In case additional Bordeaux mixture is being used as a fungicide, the entire quantity of copper sulphate solution and lime may be added to one-third of the tank of water, the raw oil added, and the whole pumped back into itself for a few minutes. The filling of the tank may then be completed.

PROPRIETARY SOAPLESS EMULSIONS

A number of proprietary soapless emulsions have made their appearance on the market, and for the most part these products have given very satisfactory results. Most of them are thick pastes, containing 65 to 85 per cent oil. They should be used at the concentrations recommended by the manufacturers on the label.

DILUTION OF OIL EMULSIONS

The dilutions recommended for lubricating-oil emulsions are usually expressed as percentages of oil, and refer to the content of actual oil, rather than to the proportion of stock used. The recommendations assume that the stock contains some standard proportion of oil—usually 66 per cent. On this basis, to obtain 100 gallons of a 2 per cent diluted spray 3 gallons of stock will be required; for 3 per cent of oil 4½ gallons will be required; for 4 per cent of oil 6 gallons will be required. If the stock material contains more or less oil than the proportion resulting from the use of the standard formula, the proper quantity of stock to use may be ascertained from Table 1.

TABLE 1.—*Dilution table for use of stock lubricating-oil emulsions of different oil contents*

Oil content of stock material (per cent)	Quantity of stock[1] needed to obtain given percentages of oil in 100 gallons of diluted material			
	1 per cent	2 per cent	3 per cent	4 per cent
	Gallons	*Gallons*	*Gallons*	*Gallons*
50	2	4	6	8
55	2	3¾	5½	7¼
60	1¾	3½	5	6¾
65	1¾	3¼	4¾	6¼
70	1½	3	4½	5¾
75	1½	2¾	4	5½
80	1¼	2½	3¾	5
85	1¼	2½	3¼	4¾
90	1¼	2¼	3½	4½

[1] Fractions rounded off in each case to next higher one-fourth gallon.

MISCIBLE OILS

A number of reliable and effective proprietary miscible oils are available on the market. These oils differ in composition, and no specific directions will be given here for their use. In most cases the manufacturers recommend their use at 5 per cent or at slightly greater strengths (1 to 20 or 1 to 15), although in some instances the recommendations have been reduced to 3 per cent or 4 per cent (1 to 33 or 1 to 25).

Miscible oils have certain advantages over the emulsions; they are very convenient to use, the mixing operations do not require such close supervision as is necessary with the emulsions, they may be stored indefinitely, and they do not freeze readily.

The relative covering powers of the miscible oils and the lubricating-oil emulsions appear to be approximately equal, according to tests conducted by the Bureau of Entomology.

OIL SPRAYS FOR SUMMER USE

The oil sprays in common use for dormant spraying, when employed at effective strengths, are unsafe on trees in foliage, although in emergency cases certain emulsions of ordinary lubricating oil have been used on apple (but not on peach) with comparatively little injury. In recent years it has been found that highly refined oils of the type used for medicinal purposes, and often referred to as "white," or "crystal," oils, are much less injurious to foliage and fruit than the ordinary lubricating oils, and that the white oils may be used to a certain extent during the growing season. These summer oils are available chiefly in the form of soapless emulsions of the paste type. While favorable results have been reported from the use of these oils under some conditions, injurious effects have been noted in other cases, and the margin of safety appears to be a very narrow one. Further experimental work is needed before general recommendations can be made as to the summer use of white oils in deciduous-fruit orchards.

MIXTURES OF OIL SPRAYS WITH OTHER MATERIALS

WITH BORDEAUX MIXTURE AND COPPER SULPHATE

Practically all oil emulsions, as well as some miscible oils, mix readily with Bordeaux mixture, and such combination sprays are in rather extensive use in some sections in the dormant spraying of peach trees. The Bureau of Plant Industry has found that this combination spray gives satisfactory results in the control of peach leaf curl. In the control of the San Jose scale, however, the addition of full-strength Bordeaux mixture to oil emulsion has been found to reduce to a certain extent the effectiveness of the oil, but this may be overcome by a moderate increase in the strength of the oil. For example, if 2 per cent of oil used alone has been found necessary for the control of the San Jose scale, the addition of full-strength Bordeaux mixture should be compensated for by an increase in the oil content to 2½ or 3 per cent. The oil-Bordeaux combination has also been used to a limited extent on apple in the delayed-dormant application, and is believed to have value at this stage of the development of apple foliage in the control of apple scab. Too little is known about the safety of this practice to recommend its use.

Copper sulphate, at concentrations of 2 pounds to 4 pounds in 50 gallons, also forms a fairly good mixture with most of the oil emulsions, and has been used to a limited extent in the dormant spraying of peach trees, but has in some cases caused injury to peach wood.

When Bordeaux mixture and oil emulsion are combined, the Bordeaux and oil together tend to form a separate layer in the spray tank, although the oil itself does not separate out. Moderate agitation is necessary to overcome this tendency. The copper sulphate-oil emulsion mixture creams very rapidly, and requires vigorous agitation if a uniform spray is to be maintained.

In summer spraying of apple, Bordeaux mixture appears to cause an even greater reduction in the effectiveness of oil in the control

of the scale, and if emergency applications for scale control appear necessary during the summer, the oil should be applied separately, and not combined with Bordeaux mixture.

WITH LIME-SULPHUR

Combinations of lubricating-oil emulsions with lime-sulphur have been found very injurious to the foliage of deciduous-fruit trees, and in some cases have caused damage to dormant peach wood. Little is to be gained by the use of such combinations, and their general use is not recommended.

INJURY FROM OIL SPRAYS

While the application of oil sprays during the dormant period has in some cases caused injury to fruit trees, the extensive use of many kinds of oil emulsions for dormant spraying during the last seven or eight years, under all conceivable weather conditions, warrants the statement that there is little danger from the use of a properly prepared oil emulsion or miscible oil while the trees are fully dormant. In the Northwest, a few cases of serious injury to apple trees have apparently resulted from late fall or early winter applications of oil sprays, followed by sudden drops to subzero temperatures. This condition has not been observed, however, when the spraying was done in late winter or early spring, even if followed by very cold weather. As a general precaution, however, many growers do not spray when the temperature is below 40° F., especially along toward night when an unusual drop in temperature seems to be in prospect.

The foliage of fruit trees is of course more subject to injury than the wood, and the application of the less refined oils after the buds begin to swell always involves a certain degree of risk. In the Northwest the application of the less refined oils to apple trees after the buds have commenced to swell have, under some conditions, caused considerable injury to the fruit buds, and in that section the recommendation is made that the dormant spraying be completed before the buds start to swell. In the eastern and middle-western fruit sections applications of properly made oil emulsions or miscible oils during the delayed-dormant period have seldom caused appreciable injury. The danger increases as the foliage pushes out, and after the leaves have reached a length of a half inch the more highly refined oils should be employed if the use of an oil spray is found necessary.

Fears have been expressed from time to time that the continued use of oil sprays over a period of years might ultimately result in cumulative injury. The occurrence of such cumulative injury is very difficult to demonstrate or to disprove, but the healthy condition of thousands of orchards which have received annual dormant applications of oil sprays over a period of eight or more years would indicate that this danger is not a very serious one.

As already indicated, none of the summer or white oils can be considered completely noninjurious to foliage, although some of them have been used without serious consequences.

INSECTS FOR WHICH OIL SPRAYS MAY BE USED

Brief mention will be made of the more common insects which may be controlled by the use of oils sprays, together with the concentrations of oil emulsion needed for effective work. The miscible oils should, in most cases, be used at somewhat greater strengths than those indicated for the oil emulsions; more exact information as to the proper dilution will be found on the label. The mention of an insect pest in this discussion does not necessarily mean that oils are recommended to the exclusion of other sprays; in many cases lime-sulphur or other materials may be used with an equal degree of effectiveness, and under some circumstances may be preferable.

The list of scale insects is by no means a complete one, but includes representatives of most of the important groups. If scale insects not specifically mentioned here become troublesome, the recommendations made for closely similar species will in most cases be found effective.

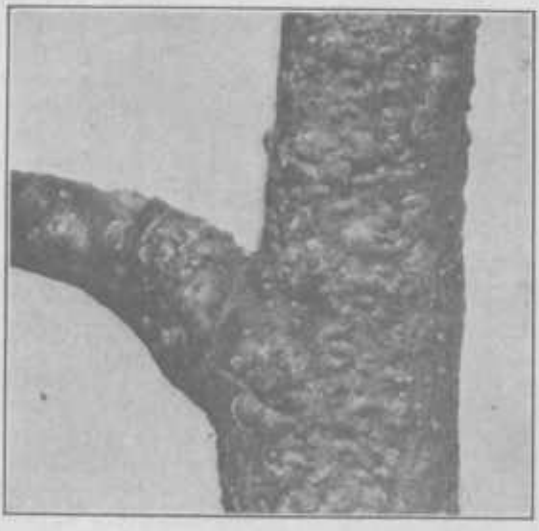

FIGURE 5.—Portion of apple twig encrusted with the San Jose scale. Scales of all ages are shown in the illustration; the largest and the smallest ones perish during the winter. Twice natural size

SAN JOSE SCALE

The San Jose scale (*Aspidiotus perniciosus* Comst.) (fig. 5) attacks practically all orchard trees, and is well known to most fruit growers. The individuals which happen to be one-third to one-half grown at the close of the season are those which will survive the winter in middle and northern latitudes. The concentration of oil emulsion needed for the control of the San Jose scale seems to vary as between different localities. In the Middle West 2 per cent of actual oil (in the emulsion form) is sufficient if a thorough job of spraying is done. In heavy infestations, however, growers sometimes use 3 per cent of oil in order to be sure of a kill in spots that are only lightly sprayed. In other sections 3 per cent of oil has become the standard recommendation, while in the Pacific Northwest 4 per cent of oil in the form of an emulsion seems to be required for satisfactory results.

In the case of apple, if control has not been obtained during the dormant season, the use of summer oils at 1 or 2 per cent when crawlers are present in numbers is of value in partially checking the infestation. This, however, should be considered as an emergency treatment, and is not recommended as a regular practice. The foliage of peach is too susceptible to injury by oil sprays to justify

the recommendation of oil at a strength great enough to give appreciable control of the San Jose scale on peach during the growing season.

OYSTER-SHELL SCALE

The oyster-shell scale (*Lepidosaphes ulmi* L.) (fig. 6), a common pest of apple and pear in the Northern States, winters over in the egg stage underneath the scale covering which protected the mother insect. Hence, to be effective, oil sprays applied during the dormant season must pass through this thick scale covering and then penetrate the shells of the eggs. For complete kill, from 8 to 10 per cent of oil must be used, a strength which allows a rather narrow margin of safety, although it has been used a great many times with no serious injury. Fortunately the oyster-shell scale multiplies at a comparatively slow rate, and the control measures against it do not need to be so completely efficient as is necessary with the San Jose scale in most localities. In the majority of cases the sprays applied for the San Jose scale will incidentally keep the oyster-shell scale from doing serious damage.

FIGURE 6.—Portion of twig encrusted with the oyster-shell scale. During the winter the scale covering conceals and protects a loose mass of pearly white eggs. About 2½ times natural size

Good results in control have been obtained by summer applications of the white oils at 1½ to 2 per cent. These should be applied 10 days or so after the first crawlers appear (soon after apple trees are in bloom), at which time most of the eggs will have hatched, and the scale coverings over the most advanced individuals will still be thin enough to be readily penetrated by the spray. As already indicated, there is more or less danger of injury to foliage or fruit, particularly if a residue of a sulphur fungicide is present on the trees.

FIGURE 7.—Twig infested with the scurfy scale. The insect winters in the form of purple eggs, underneath the scale covering. Twice natural size

SCURFY SCALE

The scurfy scale (*Chionaspis furfura* Fitch) (fig. 7) is a pest of apple and pear, and is most abundant in the New England and Middle Atlantic States. Like the oyster-shell scale, it winters in the egg stage. During the dormant season the oil sprays seem to penetrate the scale coverings and eggs of this species somewhat more

readily than they do those of the oyster-shell scale, and lubricating-oil emulsion at 3 per cent strength has been reported to be effective. In case the scurfy scale is not controlled during the dormant season, the application of summer oils as outlined for the oyster-shell scale may be resorted to as an emergency measure.

TERRAPIN SCALE

The terrapin scale (*Lecanium nigrofasciatum* Pergande) (fig. 8), a pest of peach and plum, is to be found during the dormant season on the under sides of twigs and smaller branches as two-thirds grown females. At this time applications of 4 per cent lubricating-oil emulsion have been found effective.

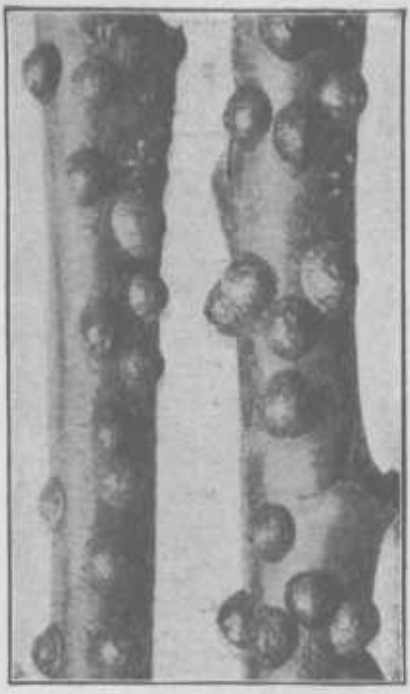

FIGURE 8.—The terrapin scale. During the winter the scales are found chiefly on the under sides of the twigs. Five times natural size

COTTONY PEACH SCALE

The cottony peach scale (*Pulvinaria amygdali* Ckll.) hibernates as nearly mature scales, clustered mostly on the east sides of twigs and smaller branches, and to some extent on the callus growth around old pruning scars and other wounds. Good results have been reported in New York State from dormant applications of 4 per cent lubricating-oil emulsions.

EUROPEAN RED MITE AND CLOVER MITE

The European red mite (*Paratetranychus pilosus* C. and F.) (fig. 9) and the clover mite (*Bryobia practiosa* Koch) pass the winter in the egg stage, on the twigs and smaller branches of apple, plum, peach, and other fruits. Applications in the late-dormant or delayed-dormant period of 3 to 4 per cent lubricating-oil emulsion have proved effective. Fall applications have failed to give satisfactory control.

If mites become troublesome during the growing season, the infestation may be fairly well controlled by the use of the summer oils at 1 to 2 per cent strength.

FRUIT-TREE LEAF ROLLER

The apple pest known as the fruit-tree leaf roller (*Cacoecia argyrospila* Walker) (fig. 10) is best controlled during the dormant season, when it is present on the trees in the egg stage. The masses of

eggs are covered with a hardened gumlike substance, and 7 to 8 per cent of oil in the spray is required to destroy the eggs under this protection.

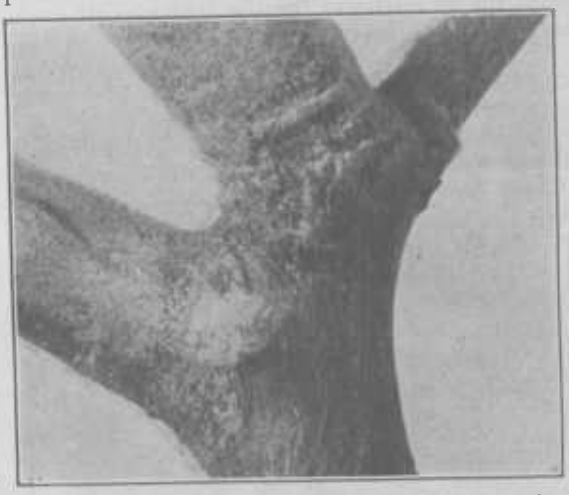

FIGURE 9.—Hibernating eggs of the European red mite. These minute eggs are of a deep red color. About 2½ times natural size

PEAR PSYLLA

The pear psylla (*Psyllia pyricola* Foerst.) (fig. 11), a serious pest in portions of the northeastern part of the United States and in southeastern Canada, hibernates as the adult "fly" in protected situations in and near the orchard, and migrates to the trees with the very first warm days of spring. At this time applications of 3 per cent lubricating-oil emulsion have given very satisfactory results. Many of the adult flies are killed, and the film of oil on the bark appears to have a great deal of residual value, reducing the number of eggs laid, and killing a high percentage of the

FIGURE 10.—Egg mass of the fruit-tree leaf roller. The eggs in this particular mass have hatched. Twice natural size

FIGURE 11.—Pear psylla adult (about 20 times natural size). The hibernating adults appear on pear trees on the very first warm days of early spring

young psyllas which hatch. In Ontario the cold-mixed Bordeaux-oil emulsion has proved the most satisfactory, and the heavier oils, those having a viscosity of 150 to 200, seem to be the most effective.

APPLE APHIDS[8]

Most fruit growers are familiar with the shiny black eggs of the apple aphids, as they are found during the winter on the young wood of apple trees. (Fig. 12.) The eggs of these species hatch in early spring, often before the buds have swelled to any extent; the exact time of hatching (with reference to the opening of the buds) varies in different sections, and with the different species of aphids involved. The standard treatment for the combined control of apple aphids and the San Jose scale in sections where both

FIGURE 12.—Eggs of apple aphids, as found during the winter on the twigs and smaller branches of apple trees. About six times natural size

FIGURE 13.—Condition of apple buds in the early part of the delayed-dormant period. The aphids are clustered on the green tips of the buds and have no protection against the spray material

are troublesome has for a number of years been winter-strength lime-sulphur and nicotine sulphate, 1 to 1,000, applied during the so-called delayed-dormant period (figs. 13, 14, and 15), just as the buds are pushing out. This combination has been found very effective in killing the newly hatched aphids, as well as many of the unhatched eggs present.

The question often arises whether it is advisable to substitute oil treatments for the lime-sulphur-nicotine mixture in orchards in which aphids must be controlled. This question is of particular importance in orchards in which the presence of the European red mite or the fruit-tree leaf roller dictates the use of an oil spray

[8] Three species of aphids are involved: The rosy apple aphid (*Anuraphis roseus* Baker), the green apple aphid (*Aphis pomi* DeG.), and the apple-grain aphid (*Rhopalosiphum prunifoliae* Fitch).

in preference to lime-sulphur. To have their maximum effectiveness in aphid control, the oil sprays must be applied after the aphids have hatched, since the oils are only partially effective against the unhatched aphid eggs; even when applied after the aphids have hatched, the oils have failed in many instances to give satisfactory control, possibly because of low temperatures at such times, although in other cases good results have been reported.

Recent experiments in New York State have indicated a high degree of effectiveness in aphid control from a mixture of a 3 per cent lubricating-oil emulsion with 40 per cent nicotine sulphate, 1 pint in 100 gallons, or 50 per cent free nicotine, four-fifths of a pint in 100 gallons, applied during the delayed-dormant period. Further experimental work and commercial experience are needed, however, before this treatment can be recommended for general adoption in sections where the application of oil sprays in the delayed-dormant period appears to be fairly safe.

FIGURE 14.—Condition of apple buds late in the delayed-dormant period. Spraying should be completed before the buds advance beyond this stage

FIGURE 15.—Much too late to make the delayed dormant application. At this stage of development the leaves and buds may be seriously injured by dormant-strength spray materials, and the aphids find shelter in the crevices between the buds, making it impossible to hit them all

There is always more or less danger of injury during the delayed-dormant period, the danger increasing as the leaves push out and increase in size. In the Northwest the opening buds seem to be especially subject to injury by oil sprays, and in that section it is recommended that the dormant applications of oil be completed before the buds swell to any extent. In other sections of the country the danger of injury seems to be less, although the oil applications should be completed considerably earlier than the stage of development shown in Figure 15.

U. S. GOVERNMENT PRINTING OFFICE: 1931

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - Price 5 cents

U. S. DEPARTMENT OF AGRICULTURE
FARMERS' BULLETIN No. 1670

LUBRICATING-OIL SPRAYS FOR USE ON DORMANT FRUIT TREES